The General Motors/DOE Hybrid Propulsion Systems Development Program

In September 1993 General Motors Corporation and the U.S. Department of Energy (DOE) signed a cost-shared, five-year Hybrid Propulsion Systems Development Program contract for $151 million. According to GM Program Manager Larry Oswald, the team's goal is to develop a production-feasible hybrid propulsion system that would allow a vehicle to have twice the efficiency of today's conventional vehicles.

The GM team has divided their program into three distinct phases.

- *Concept Definition Phase.* GM investigated propulsion system alternatives and built a hybrid technology testbed vehicle. This vehicle represents state-of-the-art technology as it existed before the development phases of the program, and it will allow rapid installation of new propulsion components as they are developed.
- *System Design Phase.* GM will build, test, and demonstrate an initial propulsion system using first-generation, purpose-built components.
- *System Development and Validation Phase.* The individual propulsion components and system-level design will be upgraded and fine-tuned for reliability, durability, cost reduction, and manufacturability. The final system will be demonstrated in the integrated test vehicle, the major deliverable of the effort.

The GM team has determined that in order to meet the goal of a 100% improvement in fuel economy, both the thermal efficiency of the heat engine and the electrical conversion efficiency of the electric drive system must be improved simultaneously. State-of-the-art technology in gas turbine and Stirling engines is being considered for the Gen1A and Gen1B System Mule Vehicles' hybrid power unit. The engines' relative performance and emissions using different types of liquid fuel is also being evaluated.

GM has chosen Optima Batteries, Inc. of Denver, CO, as its supplier of batteries for its hybrid vehicle. Optima produces lead-acid batteries with spiral cell technology which should provide improved power and cycle life over that of a conventional battery. The hybrid battery pack will consist of 60 six-volt Optima batteries. Optima is a subsidiary of the Gylling Group.

After careful consideration of many factors, the GM team will be concentrating its efforts on developing a series-drive hybrid; the team believes that a series hybrid presents cost, emissions, fuel economy, and design advantages over the alternative parallel hybrid configurations with the technologies under consideration.

The GM team is led by GM's Research and Development Center and includes several GM divisions as well as outside supplier/partners, most of whom are sharing costs. The partner roster is expected to change over time as the effort evolves.

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Current team members include:

AeroVironment	inverter and battery technologies, testing and simulation
Allison Engine Company	gas turbine engines
ARIAS Research	bi-polar lead-acid batteries
Bi-polar Technologies	bi-polar lead-acid batteries
Corning, Inc.	ceramic components
DELCO Electronics	motors/controllers
DELCO Remy	engine components
Exxon Research	fuels, infrastructure studies
GM Delphi Rochester	fuel systems, emissions controls
GM Delphi Chassis	vehicle chassis, regenerative braking
GM Delphi Harrison	thermal management
GM Delphi Indianapolis	electric drive units
GM Delphi Saginaw	electric power steering
Kyocera Ceramics	ceramic components
Optima Batteries, Inc.	lead-acid batteries
Pacific Scientific	alternators
Stirling Thermal Motors	Stirling engines
TASC	systems analysis
University of Idaho	battery research

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